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LISTS OF SPECIES

Bats of Vieques National Wildlife Refuge, Puerto Rico, Greater Antilles

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ABSTRACT: Herein, we present captures of bats from Vieques, a small subtropical island located southeast of Puerto Rico. We captured 82 individuals representing 4 species, including 59 *Noctilio leporinus*, 9 *Artibeus jamaicensis*, 9 *Molossus molossus*, and 5 *Stenoderma rufum*. All *S. rufum* and *M. molossus* were captured in subtropical moist forests, whereas both *N. leporinus* and *A. jamaicensis* were captured in both subtropical moist and dry forests. *Sternoderma rufum* is an endemic species of concern in the region. Vieques represents only the 5th island where this relatively rare species has been captured in the past 30 years. Conservation of subtropical moist forests on Vieques likely is important for the conservation and management of *S. rufum* and additional information about the natural history of all bats is warranted on Vieques.

INTRODUCTION

Vieques is a small subtropical island located 9.7 km from the southeastern coast of Puerto Rico in the Greater Antilles. Little published information exists on the distribution and habitat associations of bats on Vieques compared to bats on the nearby island of Puerto Rico (Gannon *et al.* 2005 and references therein). To date, four species of bats have been reported from Vieques including the greater bulldog bat (*Noctilio leporinus* Linnaeus, 1758), Jamaican fruit-eating bat (*Artibeus jamaicensis* Leach, 1821), Pallas's mastiff bat (*Molossus molossus* Pallas, 1766), and red fruit bat (*Stenoderma rufum* Desmarest, 1820; Gannon *et al.* 2005). To our knowledge, only *M. molossus* and *N. leporinus* have a single specific published locality of occurrence on Vieques, whereas for all other species nothing has been published yet on habitat associations.

Stenoderma rufum is a species of concern because it is an Antilles endemic (IUCN 2011). To date, only limited information is known for this species throughout its restricted distribution (Genoways and Baker 1972; Gannon *et al.* 2005). Puerto Rico represents the only island where it is captured commonly, thus where much of the information regarding its life history originates (Gannon and Willig 1994). *Stenoderma rufum* also occurs on the islands of St. Thomas and St. John (Genoways and Baker 1972; Bacle *et al.* 2008), and a single female was captured in St. Croix in 2004 (Kwiecinski and Coles 2007). On Vieques, Gannon *et al.* (2005) only reported "a juvenile red fig-eating bat was captured recently" on the island.

Herein, we report on the localities of occurrence and habitat associations for bats on Vieques. Our data will further provide baseline data for future conservation efforts and management of forests on Vieques and hopefully lead to more research on *S. rufum*. Limited prior research on bats on Vieques likely reflects that much of the island has had restricted access reflecting its former use as a U.S. Navy training facility for about six decades until 2003.

MATERIALS AND METHODS

Study site

We sampled bats at six sites at the Vieques National Wildlife Refuge (VNWR), Vieques, Puerto Rico. The refuge occupies 54% of the island (7,191 of 13,403 ha) and contains both subtropical dry and subtropical moist forests. Of our six sites, three were located in subtropical moist forests on the western side of the island (Boat Ramp Kiani, 18°07'9.2"N, 65°33'20.6"W; Punta Arenas, 18°06'51.6"N, 65°34'32.2"W; Punta Arenas 18°06'35.8"N, 65°34'30.4"W), and three were located in subtropical dry forests in south-central parts of the island (Playuela, 18°06'37.7"N, 65°24'59.5"W; Bahía de la Chiva Bridge, 18°06'46.7"N, 65°23'29.6"W; Playa Plata, 18°07'03.4"N, 65°22'36.0"W).

Sampling technique

We placed four 12-m mist nets (AviNet Inc., Dryden, NY, USA) at sites at dusk each evening at ground level along forest edges. Once bats were removed from nets, we placed each separately in a holding container. Next, we weighed each individual within 1 h of capture; measured length of forearm, tibia, tail, and ear with digital calipers; and recorded sex. All bats were released at the site of capture; a voucher photograph was taken of each species. We visited each site twice to capture bats, once during the dry season (25 June-1 July 2008) and once during the wet season (1-13 September 2008) for a total of 48 net nights. Due to the sensitive status of bats on VNWR, we documented species with photographic vouchers during our survey to secure records of occurrence on the island (see Figure 1). The four bat species on Vieques were identified by the following characteristics as well as others not listed here (see Gannon *et al.* 2005 for further details on species attributes): *N. leporinus* has long legs, enlarged hind feet and claws, and split upper lip; *A. jamaicensis* has a large-sized nose leaf and large overall size for fruit-eating bats in the region; *S. rufum* contains white patches of fur below the ear and on the shoulder, large nose leaf, and medium-sized forearm lengths for fruit-eating bats in the region; and *M. molossus* lacks wrinkles on the upper lip

and contains a partially free tail extending beyond the tail membrane.

The project was sponsored by the United States Fish and Wildlife Service at VNWR. Our capture and handling procedures of bats were approved by the Institutional Animal Care and Use Committee of the University of Nebraska at Kearney (IACUC # 060208). Coordinates of sites were obtained with hand-held global positioning units (Garmin GPSMAP 76S, Garmin Ltd, Kansas, USA) using datum WGS 84.

Results and Discussion

We captured 82 bats representing four species in mist nets at ground level (Table 1, Figure 1, Appendix). The most common species was *N. leporinus*, with 59 individuals representing 72% of captures. Nine *A. jamaicensis* and 9 *M. molossus* also were captured at sites, each representing 11% of captures. *Stenoderma rufum* was the least frequently captured species, with 5 individuals representing 6% of captures. All *S. rufum* and *A. jamaicensis* were male and all *M. molossus* were female. Male *N. leporinus* were captured more frequently (71%) than females and were consistently larger than females (Table 2). Details of body weight, length of tibia, tail, ear, and forearm are summarized for each species in Table 2.

All *S. rufum* and *M. molossus* were captured in subtropical moist forests of the island whereas *N. leporinus* and *A. jamaicensis* were captured in both subtropical moist and dry forests. Dominant species of plants by visual estimation where *S. rufum* was captured consisted of 75% *Cocos nucifera* Linneaus, 10% *Coccoloba uvifera* (Linneaus) Linneaus, 5% *Sansevieria trisfaciata* Prain, 5% *Leucaena leucocephala* (Lamark) De Wit, and 5% *Bursera simaruba* (Linneaus) Sargent. At this site, the ocean was about 44 m to the west, and mangroves (mainly *Rhizophora mangle* (Linneaus) and *Avicennia germinans* (Linneaus) Linneaus) were a few hundred meters to the east and southeast. The highest point on Vieques (Monte Pirata, 301 m elevation) was 3 km southeast of this location.

Bats are important ecological components of tropical ecosystems because they provide vital functions such as pollination and seed dispersal for many plants (Humphrey and Bonaccorso 1979; Charles-Dominique 1986; Gannon and Willig 1994). Bats on Vieques are the only native mammals (Gannon and Willig 1992; 1997), and species such as *A. jamaicensis* and *S. rufum* likely provide these ecological services for plants after disturbances such as hurricanes. Puerto Rico contains 13 extant species of bats with only four species being reported from the nearby island of Vieques (Gannon *et al.* 2005). During our limited survey, we documented the four species previously reported from the island (Gannon *et al.* 2005). Although few species occur on Vieques, one Antilles endemic, *S. rufum*, does inhabit this small island but occupies a different habitat than on Puerto Rico.

Based on the equation, $S = 2.137 \times A^{0.214}$ for species richness (S) of bats on Antillean islands (Fig. 7 in Gannon *et al.* 2005), six species of bats should occur on Vieques based on its area (A); however, a species/area curve based on bat fauna of the West Indies shows that Vieques (area of 132 km^2) should contain about four species of bats (Genoways *et al.* 2007). Thus, the species known to occur on Vieques are at or below predicted values for islands of similar size. With additional sampling, we suspect that additional bats will be reported on Vieques due to the proximity of this island to the larger island of Puerto Rico with its greater diversity of species. Although our limited survey provides new localities and habitat associations for bats on Vieques, our brief mist-net survey needs to be extended over a period of years with a longer duration of survey effort to better understand the species composition on the island (Larsen *et al.* 2007).

On Puerto Rico, most of its 13 species roost in caves (Rodríguez-Durán 1998; Gannon *et al.* 2005), but with few caves or cave-like structures on Vieques, many cave-obligate species likely will not be observed on the island even with additional surveys. For the four species known from Vieques, roost sites commonly used by each species are available. Although *N. leporinus* and *A. jamaicensis* roost in caves, both species also commonly roost in trees (Hood and Jones 1984; Kunz and McCracken 1996). We captured 51 of 59 *N. leporinus* near a suspected tree roost at Playuela in an area consisting mainly of red mangroves (*R. mangle*). On Puerto Rico, *S. rufum* roosts in foliage and *M. molossus* commonly roosts in buildings (Gannon *et al.* 2005); both these types of roosts also occur on Vieques. We surmise that *S. rufum* roosts in the foliage of trees on Vieques, as it does on Puerto Rico (Gannon and Willig 1997), but likely in different tree species because our captures were near sea level in a different habitat than where *S. rufum* was studied in Puerto Rico.

Given their proximity and abundance on Puerto Rico, the absence of several species of bats on Vieques is notable. The Antillean fruit-eating bat (*Brachyphylla cavernarum* Gray, 1834) is a robust bat common throughout the region (Swanepoel and Genoways 1983; Gannon *et al.* 2005) known for its catholic roosting and dietary habits (Swanepoel and Genoways 1983), but this species is a cave-obligate species throughout the region (see Swanepoel and Genoways 1983). Additional species of bats that may be documented on Vieques with further survey efforts include the big brown bat (*Eptesicus fuscus* (Palisot de Beauvois, 1796)), eastern red bat (*Lasiurus borealis* (Müller 1776)), and Brazilian free-tailed bat (*Tadarida brasiliensis* (I. Geoffroy Saint-Hilaire, 1824)).

Hurricanes have been shown to be detrimental to *S. rufum* in Puerto Rico (Gannon and Willig 1994; Jones *et al.* 2001). For example, after hurricane Hugo passed over Puerto Rico, captures of *S. rufum* decreased 80% and it took five years for populations to rebound (Gannon *et al.* 2005). Hurricanes may affect habitat and reproduction for *S. rufum* and other bats on Vieques in a similar manner. Hurricane-aided dispersal of individual bats from Puerto Rico or the Virgin Islands to Vieques may affect the genetic richness for *S. rufum* on the island, as was demonstrated with *A. jamaicensis* on Grand Cayman (Fleming and Murray 2009). Moreover, Fleming and Murray (2009) suggested that the occurrence of *S. rufum* on two of the Virgin Islands east of Puerto Rico, St. John and St. Croix, potentially may have been aided by hurricanes.

Conservation priority

Stenoderma rufum was observed in subtropical moist

forests at low elevations on Vieques during our limited survey, thus conservation of subtropical moist forests on Vieques appears important for the persistence of this species. In contrast, most *S. rufum* have been captured from the montane Luquillo Experimental Forest on Puerto Rico (Gannon and Willig 1994; Gannon *et al.* 2005). It is therefore unclear as to what type of forest constitutes a preferred habitat and why *S. rufum* was only observed at lower elevations and in drier habitats on Vieques than on Puerto Rico. Additional inventory surveys along with the radio-tracking of bats is warranted to better understand the ecology and conservation demands of this species on Vieques and how those differ from populations on Puerto Rico. Determination of the subspecific status of *S. rufum* on Vieques also is warranted to further aid in conservation efforts.

Table 1. Summary of bats captured in mist nets on the island of Vieques, Puerto Rico, from 24 June to 13 September 2008. Three sites were in a subtropical moist forest on the west side of the island (Moist) and 3 sites in a subtropical dry forest on the south-central part of the island (Dry). Number of sites represents the number of sites where the species were captured; total sites visited equaled six.

	No. of individuals		Percentage of captures by habitat		
Species	Male	Female	Dry	Moist	No. of sites
Noctilio leporinus	42	17	68.3 %	3.6 %	4
Artibeus jamaicensis	9	--	--	5.0 %	4
Molossus molossus	--	9	9.8 %	1.2 %	2
Stenoderma rufum	5	--	--	6.1 %	1
Totals	56	26	87.9 %	12.1 %	

Figure 1. Four species of bats observed from the island of Vieques, Puerto Rico, in 2008. A) *Noctilio leporinus*, 8 September, Playuela; B) *Artibeus jamaicensis*, 25 June, Bahía de la Chiva; C) *Molossus molossus*, 27 June, Punta Arenas; D) *Stenoderma rufum*, 29 June, Punta Arenas.

Table 2. Mean body weight (g) and mean length (mm) of forearm, tail, tibia, and ear of bats captured on Vieques, Puerto Rico, from 24 June 2008 to 13 September 2008. All measurements were taken within 1 hour of capture. Numbers in parentheses represent sample size, and numbers below means represent minimum and maximum values.

Species	Body weight (g)		Forearm length (mm)		Tail length (mm)		Tibia length (mm)		Ear length (mm)	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Noctilio leporinus	67.3 (42) 49.0-85.0	61.9 (17) 54.5-72.0	83.4 (42) 78.6-86.6	83.2 (17) 80.4-85.8	25.2 (42) 20.9-32.7	26.1 (17) 22.0-30.6	39.2 (42) 36.2-48.8	38.1 (17) 34.6-41.8	22.4 (42) 13.6-26.5	22.8 (17) 15.4-26.6
Artibeus jamaicensis	47.1 (9) 42.0-56.0	--	57.4 (9) 52.3-61.6	--	--	--	23.9 (9) 21.9-26.1	--	13.6 (9) 10.8-16.8	--
Molossus molossus	--	18.2 (9) 14.5-24.0	--	38.3 (9) 35.3-40.6	--	33.6 (9) 30.5-39.1	--	13.1 (9) 10.3-14.8	--	8.1 (9) 4.9-9.3
Stenoderma rufum	26.7 (5) 25.0-28.0	--	44.9 (5) 41.3-50.1	--	--	--	18.7 (5) 17.6-20.7	--	12.9 (5) 10.1-15.9	--

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Appendix. Netting localities for bats in Vieques National Wildlife Refuge, Vieques (Puerto Rico) in 2008. Dates of capture are followed by parentheses containing the number of male and female individuals for each species. Abbreviations for species are as follows *Noctilio leporinus* (NOLE), *Artibeus jamaicensis* (ARJA), *Molossus molossus* (MOMO), and *Stenoderma rufum* (STRU).

Subtropical Dry Forests: Playuela, 18°06'37.7"N, 065°24'59.5"W; 1 July (NOLE 14♂♂, ARJA 3♂♂) and 8 September (NOLE 22♂♂ and 15♀♀). Bahía de la Chiva Bridge, 18°06'46.7"N, 065°23'29.6"W; 25 June (ARJA 1 ♂) and 6 September (no bats). Playa Plata, 18°07'03.4"N, 065°22'36.0"W; 30 June (no bats) and 4 September (NOLE 1♂).

Subtropical Moist Forests: Boat Ramp Kiani, 18°07'9.2"N, 065°33'20.6"W; 26 June (no bats) and 2 September 2008 (no bats). Punta Arenas, 18°06'51.6"N, 065°34'32.2"W; 27 June (NOLE 2♂, ARJA 1♂, MOMO 3♀♀) and 10 September (NOLE 1♀, MOMO 1♀). Punta Arenas 18°06'35.8"N, 065°34'30.4"W; 29 June (NOLE 2♂, ARJA 2♂, MOMO 5♀♀, STRU 5♂♂) and 10 September (NOLE 1♀, MOMO 1♀).